Detection of Fatigue Cracks at Rivets with Self-Nulling Probe

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A new eddy current probe developed at NASA Langley Research Center has been used to detect small cracks at rivets in aircraft lap splices [1]. The device has earlier been used to detect isolated fatigue cracks with a minimum detectable flaw size of roughly 1/2 to 1/3 the diameter of the probe [2]. The present work shows that the detectable flaw size for cracks originating at rivets can be greatly improved upon from that of isolated flaws. The use of a rotating probe method combined with spatial filtering has been used to detect 0.18 cm EDM notches, as measured from the rivet shank, with a 1.27 cm diameter probe and to detect flaws buried under the rivet head, down to a length of 0.076 cm, using a 0.32 cm diameter probe.

The Self-Nulling Electromagnetic Flaw Detector induces a high density eddy current ring in the sample under test. A ferromagnetic flux focusing lens is incorporated such that in the absence of any inhomogeneities in the material under test only a minimal magnetic field will reach the interior of the probe. A magnetometer (pickup coil) located in the center of the probe therefore registers a null voltage in the absence of material defects. When a fatigue crack or other discontinuity is present in the test article the path of the eddy currents in the material is changed. The magnetic field associated with these eddy currents then enter into the interior of the probe, producing a large output voltage across the pickup coil leads. Further details of the operating principles of the probe are available in the literature [2-3].

Changes in the output voltage of the Self-Nulling probe are seen whenever the induced eddy currents flow directly under the pickup coil of the device. When the probe is scanned across a rivet, the interface between the rivet and the base metal inhibits the flow of the eddy currents. Some of the induced currents are therefore “pushed” under the pickup coil, causing an increase in the magnetic field linking the sensor. This results in an increase in the output voltage of the probe. A fatigue crack emanating from the rivet will further alter the induced current path so that a greater eddy current density will flow under the pickup coil and a larger output voltage will be recorded.

The inspection for small flaws at rivets becomes difficult as output voltage changes due to variations in the rivet fit begin to outweigh those due to small fatigue cracks. Rivet to rivet variations have been seen to produce larger voltage changes than cracks which due not extend appreciably beyond the rivet head. The rotating probe method eliminates rivet to rivet variations by recording changes in the output voltage of the probe as it is scanned a fixed radius about the center of the rivet under test. A fatigue crack is then displayed as an increase in the output voltage of the probe as it passes the angular position of the flaw. The minimum detectable flaw size is increased over isolated flaws because the presence of the rivet produces an increased current density at the rivet/base metal interface [4]. A small flaw therefore disrupts the flow of more of the induced current when it is emanating from a rivet than when it is away from material boundaries.

Spatial filtering has been added to the rotating probe method in order to distinguish voltage increases caused by fatigue cracks from changes due to misalignment or tilt of the rivet as well as from misalignment of the probe with the rivet center. These latter two effects will cause a low frequency periodic oscillation of the output voltage as the probe circles the rivet while a fatigue crack will produce a much sharper peak in the output. Fourier filtering of the data was therefore used to eliminate the low frequency components of the output voltage [4].

Fig. 1a displays a cscan of a 4 mm rivet joining two 1 mm thick Al. 2024 plates. A 1.5 mm EDM notch was machined into the top plate before the rivet was installed. The rivet head completely covered the notch so that no visible sign of damage was present. The cscan image of fig. 1a shows only a slight increase in the output voltage at the location of the hidden notch, pointing directly toward the left hand side of the page. The data obtained with the rotating probe method, shown in fig. 1b, clearly indicates the location of the flaw, 275° clockwise from the top of the page.

Fig. 2 displays both the processed and unprocessed rotating probe results for a 0.76 mm EDM notch under a 4 mm rivet joining two 1 mm thick Al. plates. The data is displayed for two complete rotations of the probe about the rivet head. Although the flaw causes only a slight change in the raw data, the extremely small EDM notch, hidden deep under the rivet head, is

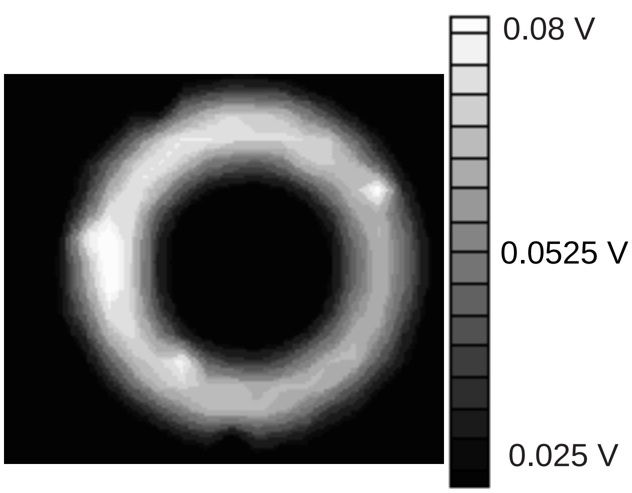

Fig. 1a Cscan image of rivet over 1.5 mm EDM notch.

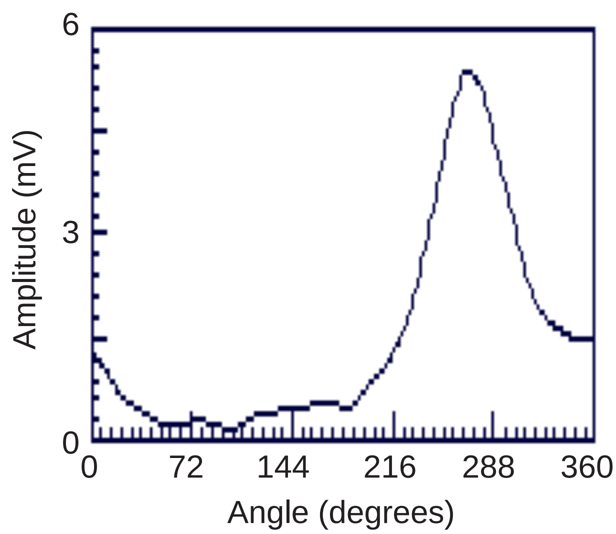

Fig. 1b Rotating probe data for rivet over 1.5 mm EDM notch.

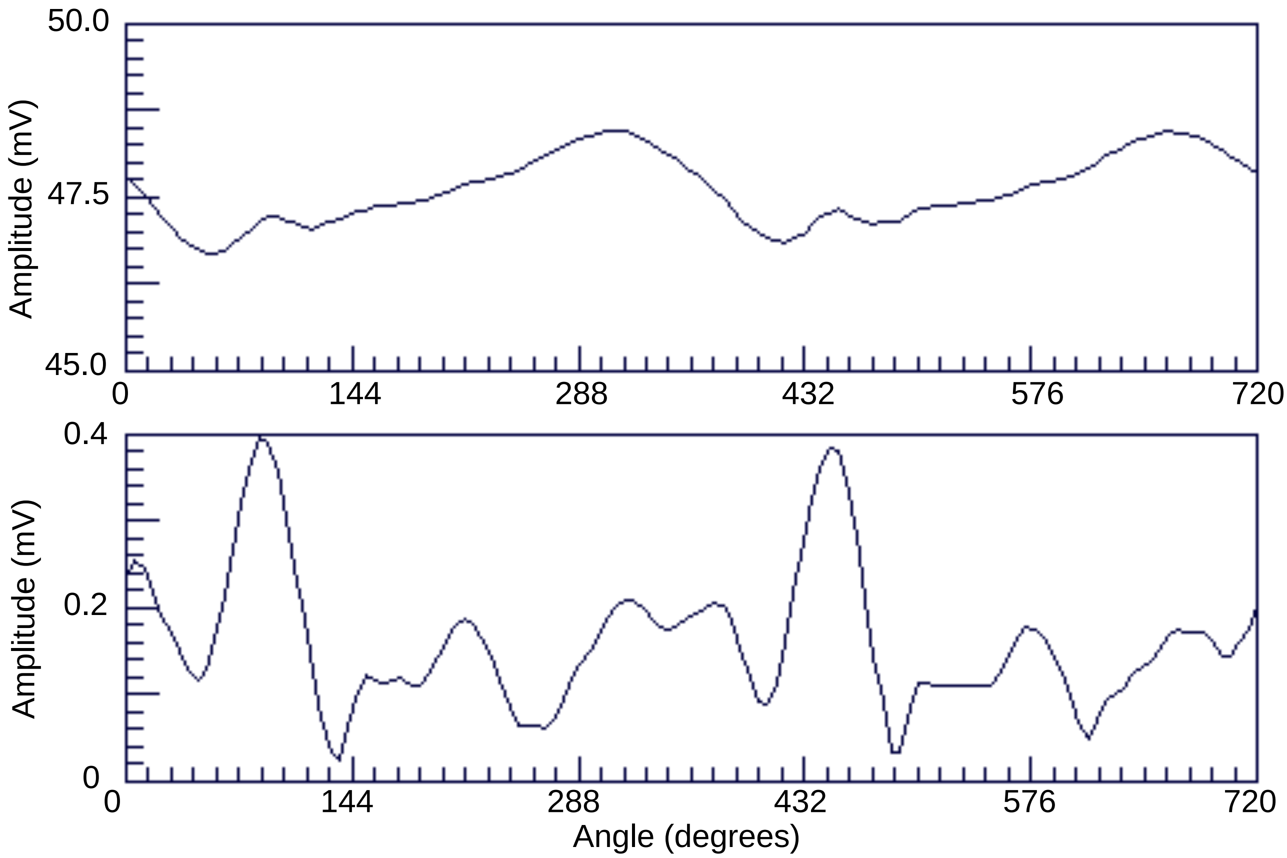

Fig. 2 Raw and processed rotating probe data for rivet covering 0.76 mm EDM notch.

apparent in the processed data at 90° and again at 450°. No indication of the defect could be seen in the cscan results.

REFERENCES

1. J.W. Simpson, B. Wincheski, M. Namkung, J.P. Fulton, R.G. Todhunter, and C.G. Clendenin, "Flux Focusing Eddy Current Probe and Method for Flaw Detection," Patent Pending.

2. B. Wincheski, J.P. Fulton, M. Namkung, S. Nath and J.W Simpson, "Self-Nulling Eddy Current Probe for Surface and Subsurface Flaw Detection," *Materials Evaluation*, Vol. 52/ Number 1 (January 1994).

3. B. Wincheski, M. Namkung, J.P. Fulton, J.W. Simpson, and S. Nath, "Characteristics of Ferromagnetic Flux Focusing Lens in the Development of Surface/Subsurface Flaw Detector," Submitted to *Review of Progress in QNDE*, Brunswick ME (August 1-6 1993).

4. Work in progress.